Forecasting Using Artificial Neural Networks and Aggregate Production Planning and Dynamic Model of Inventory Control for Rib and Single Knit Fabric

by Lina Gozali

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PARALLEL SESSION SCHEDULE
Monday, 3 Agustus, 2020

Room : Conference Room 5
Time : 13.00 – 15.00
Track : Mechanical & Industrial Engineering

NO	SCHEDULE	PAPER TITLE	AUTHORS	INSTITUTION
1	13.00-13.15	SPHC Material Inventory Control Analysis in Project VI01 Centralized By The EOQ Method In Automotive Company Indonesia	Bethriza Hanum, Jakfat Haekal, Dian Eko Prasetio	Universitas Mercu Buana, Universitas Islam As-Syafiiyah
2	13.15-13.30	Application of Single Minute Exchange of Die (SMED) on HPDC DC350T Line Casting to Reduce Changeover Time of Dies Engine Block	Hendra, Fandi Irawan Setioko, Yogy Yayang Saputra, Moh. Haris, Dady Kadarsan, Hernadewita	University of Sultan Ageng Tirtayasa, Mercu Buana University
3	13.30-13.45	Implementation of Quality Function Deployment (QFD) to Improve Service Quality at Marine Cilandak Hospital	Hermiyetti, Jacob Indra Efrialdi, Chiven, Rahmawati, Ramli, Hernadewita	University of Bakrie, Mercu Buana University
4	13.45-14.00	Overall Equipment Effectiveness (OEE) and Six Big Losses Analysis in Laboratory Industry: A Case Study in PT. IUS Jakarta	Hernadewita, Afifulloh, Susiyanti Nurjanah, Ahmad Rozak, Amalina Shadrina, Hendra	Mercu Buana University, University of Sultan Ageng Tirtayasa
5	14.00-14.15	Experimental Study on The Crashworthiness Response of Hybrid Al/GFRP Crash Box Structures Under Axial Compression Loading	Citra Asti Rosalia, Ichsan Setya Putra, Tatacipta Dirgantara, Annisa Yusuf, Bambang K. Hadi	Institut Teknologi Bandung
6	14.15-14.30	Forecasting using Artificial Neural Networks and Aggregate Production Planning and Dynamic Model of Inventory Control for Rib and Single Knit Fabric	Lina Gozali	Universitas Tarumanagara
7	14.30-14.45	Suggestion of Raw Material Warehouse Layout Improvement using Class-Based Storage Method (Case Study of PT XYZ)	Lina Gozali, Iveline Anne Marie, Natalia	Universitas Tarumanagara
8	14.45– 15.00	A Proposal of Image-Based Measurement instead of Laser-Based Measurement for Indoor Application	John Reigton Hartono, Oei Fuk Jin	Universitas Tarumanagara

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FORECASTING USING ARTIFICIAL NEURAL NETWORKS AND AGGREGATE PRODUCTION PLANNING AND DYNAMIC MODEL OF INVENTORY CONTROL FOR RIB AND SINGLE KNIT FABRIC

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Forecasting Using Artificial Neural Networks and Aggregate Production Planning and Dynamic Model of Inventory Control for Rib and Single Knit Fabric

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Abstract. PT. ZYX is a textile and garment industry. The important department of this company is the knitting department that knits yarn into cloth, which will be used for the garment production of garment. Companies often experience shortages of stock to conduct production activities to meet consumer needs. In addition, the fluctuate demand sometimes does not match the available resources. This condition lead to the increasing of inventory costs. Based on the existing problems .The aim of this research are forecasting demand with Artificial Neural Network (ANN) method, calculating the production aggregate, controlling the cost of inventory control procurement, and designing a production planning inventory control system. Forecasting results are the input data to calculate the aggregate total production and the total inventory cost. Mixed Strategy is the best solution method for PT.ZYX, with a total cost of Rp 2.435,878.117.86, -. The best aggregate method for PT. ZYX is a mixed strategy method, because it gives the smallest total production cost of Rp 2,355,466,975. The inventory control is classified as dynamic inventory can save cost for 19.27% in RIB 1x1 product; 36.67% in RIB 2X1 product; 2.01% at RIB 5X2 product; 60.52% for single knit product.

1. Introduction

The company's management system is an important thing in managing the company, such as raw materials, demand, production, and the level of consumer demand.[1] Companies must determine the best level of optimization, so that resources can be used optimally. For achieving the level of the optimization, the company needs to plan the production system and to control the raw materials requirement properly. The availability of raw materials is important in production activities to fulfil the market demand. These efforts can reduce cost such as the old cost of storing raw materials in the warehouse. The aim of this research are forecasting demand with ANN, calculating the production aggregate, controlling the cost of inventory control procurement, and designing a production planning inventory control system.

2. Literature Review

2.1. Normality Data Test

Normality Data test is a test that is used to determine whether or not normal for each variable [2]

2.2. Forecasting Using Artificial Neural Network

This research use Backpropagations Artificial Neural Network, this method supervised learn in generally used to change the weights that are interconnected between neurons in the hidden layer. [3]
The data to be processed must be normalized first because it's related to the sigmoid function (0,1). Normalization of data uses the following formula equation [4]:

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$$x' = \frac{0{,}8(x-a)}{b-a} + 0{,}1 \quad (1)$$

description, a = minimum data, b = maximum data.

2.3. Aggregate Planning

Aggregate planning estimates the amount that will be produced in meeting demand of the production planning period. The production schedule should be adjusted to the production capacity of the company. Aggregate planning can optimize utilization of resources at once can increase the effectiveness and efficiency of the production. [5]

2.4. Autocorrelation Analysis

This analysis is to see the correlation between i observation and i-1 observation.

2.5. Inventory

Inventory is an ingredient, commodity, product, etc. which generally the stock for order fulfillment. In fact, inventory control is the most important thing in economy, trade and manufacturing.[6]

2.5.1. Inventory Control

Inventory control is an important thing in the company, because it has an impact to customer, and production activity. Inventory control must be verified with ongoing audits.[7]

2.5.2 Inventory Cost

Costs arise in procurement activities. The inventory cost is a total cost of ordering raw materials (ordering cost)/ Cr; storage cost inventory (carrying cost)/ Cc; cost of running out of inventory (shortage cost)/K. [8]

2.5.3. Inventory Models

The inventory model consists of static and dynamic models. In the static inventory model ordering is done only once, which means the amount of inventory is limited for a certain period of time. While the dynamic model of ordering is done several times and continuously. [9,10,11]

2.5.4. Dynamic Inventory Model

The dynamic inventory model is divided into three models, namely dynamic inventory with specific needs for which there is no safety stock, because the needs can be known with certainty (where the number of units per order and the order period is fixed) [12]. The second model is a dynamic inventory model with uncertainty in which the amount of material needs per period varies and the distribution of material requirements is unknow. The third model is a dynamic inventory model containing risks, the number of times the ordering of materials is carried out more than once and only the probability distribution of the needs is known [13]. The following formulas used are:
Annual total Inventory cost (TIC)

$$TC = \frac{12cr}{t} + \frac{tZ.C.Cc}{24} + SS.\,C.\,Cc + \frac{12k}{t}\int_{R+w}^{\infty} f(y)\,dy \quad (11)$$

A variety of usage will allow out of stock condition. This happens if the demand deviate from the prediction. The safety stock is needed to calculate for reducing the demand fluctuations. Total Security Inventory being the Safety Stock unit; Average needs / month is Z units, so the average needs / year is 12.Z units; Standard Deviation is S unit, so the standard deviation during lead time is S.T unit; Lead Time is T unit, so the requirement during lead time is T.Z unit and Possible Delay in inventory is $\int_{R+w}^{\infty} f(y)\,dy$.The formula is a large value of the shaded area, and its value can be seen in the ordinates of normal probability distribution table. Therefore the formula translates into, as follows

Deviation standards when Leadtime (Si) formulated as follows:

$$(Si) = s\sqrt{LT} \quad (12)$$

description = Deviation standard, LT = lead time

Ordering Schedule Time (t) formulated as follows:

$$t = \frac{12 \cdot k \cdot f(R+w)}{Cc} \quad (13)$$

description k = out of stock cost, f(R+w)= normal distribution in the lead time period, Cc = Carrying Cost

Normal distribution of needs when Lead Time formulated as follows:

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$$f(R+w) = \frac{1}{s\sqrt{LT}} g(w) \quad (14)$$

description $s\sqrt{LT}$ = safety stock (SS), $g(w)$ = the probability distribution stated in the normal curve table ordinate.

The probability distribution expressed in the normal curve ordinate formulated as follows:

$$g(w) = \sqrt{(Si)^2 \left(\frac{2CC_cCr}{z \cdot k^2}\right)} \quad (15)$$

description Si = Deviation standard when lead time, C= raw material cost per unit, Cc = Carrying cost per unit, Cr= Ordering Cost, z = average needs per month, K= Shortage Cost

Optimal order number (Xo) formulated as follows:

$$Xo = Z.t \quad (16)$$

Re-order point (P) formulated as follows:

$$ROP = SS + (LT.Z) \quad (17)$$

with safety stock, then the average amount of inventory per year is $\frac{1}{2}\left(\frac{tz}{12}\right) C \cdot Cc$. So total inventory cost per year formulated as follows:

$$TC = \frac{12cr}{t} + \frac{tZ.C.Cc}{24} + SS.\,C.\,Cc + \frac{12k}{t}\int_{R+w}^{\infty} f(y)\,dy \quad (18)$$

description $\frac{12\,Cr}{t}$ = ordering cost per year, $\frac{t.Z.C.Cc}{24}$ = annual carrying cost, SS.C.Cc = buffer stock cost, and $\frac{12\,K}{t}\int_{R+W}^{\infty} f(y)\,dy$ = shortage cost per year

3. Research Methodology

The first step conducts a preliminary research observations and interviews at PT. ZYX. The second step conducts a preliminary study of the existing problems. The third step identifies the existing problem and determine the limitations of the study so that research is focused on the goal. The fourth step determines the formulation and identification of the problem, determining the research objectives to answer the existing problem formulation. The fifth step conducts a literature study with a field observation study. The sixth step collects the research data. The seventh step tests the normality and adequacy of the data. If the data are not out of the limit, then forecasting is done if it is not then the data must be collected again. The eighth step chooses the best forecast, followed by testing of the forecast pattern along with controlling the forecast with tracking signal method. The ninth designs an aggregate and calculate the total inventory cost. The final step produces system conclusions and suggestions the result of this research to the company. The stages of the methodology can be seen in Figure 1.

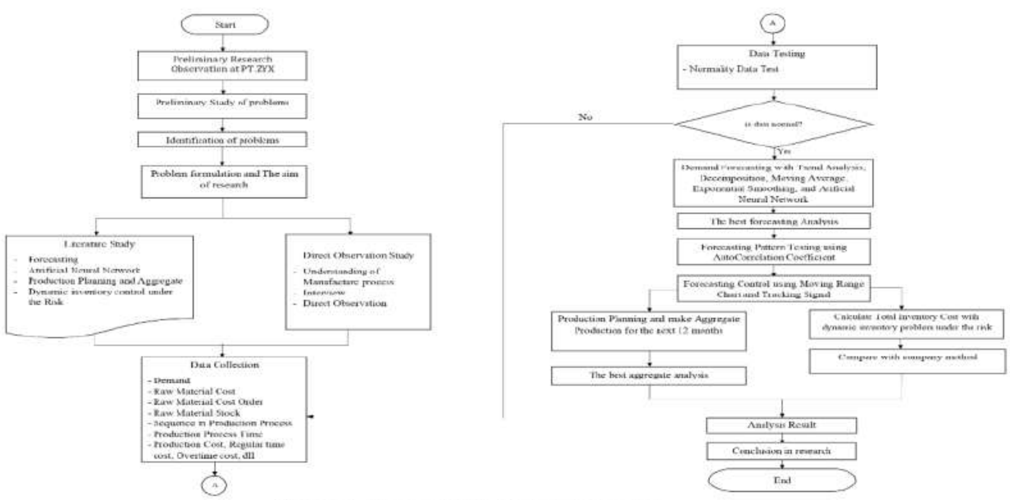

Figure 1 . Research Methodology Flowchart

4. Results and Discussion

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4.1. Demand data

Demand data of RIB and SK from September 2016 – August 2019 can be seen in Table 1.

Table. 1 Demand product of PT. ZYX

Periode	RIB 1X1	RIB 2X1	RIB 5X2	SK	Periode	RIB 1X1	RIB 2X1	RIB 5X2	SK
Sep-16	114,821	63,947	5,093	13,984	Mar-18	88.800	51.800	7.400	15.800
Oct-16	109,005	50,480	9,515	17,150	Apr-18	90.757	50.302	18.781	2.660
Nov-16	85,498	51,761	16,791	24,830	May-18	92.640	51.176	10.584	2.400
Dec-16	79,057	34,875	3,888	8,125	Jun-18	34.119	17.658	3.123	-
Jan-17	61,892	47,717	10,616	23,148	Jul-18	65.859	54.268	18.524	1.850
Feb-17	67,802	55,912	19,028	9,700	Aug-18	107.538	62.731	8.962	4.200
Mar-17	122,713	68,719	4,909	19,100	Sep-18	110.017	65.161	11.102	10.403
Apr-17	103,860	60,585	8,655	4,750	Oct-18	103.710	60.498	8.643	2.200
May-17	137,167	69,672	10,886	775	Nov-18	94.623	49.950	6.127	10.100
Jun-17	73,780	36,890	8,330	1,768	Dec-18	73.331	41.731	11.598	18.060
Jul-17	100,597	47,250	4,573	6,330	Jan-19	110.070	64.208	9.173	11.025
Aug-17	92,394	57,942	6,264	11,732	Feb-19	94.375	75.500	18.875	9.700
Sep-17	112,625	58,475	9,100	5,300	Mar-19	133.035	47.513	9.503	5.515
Oct-17	105,408	49,410	9,882	7,300	Apr-19	112.801	52.062	8.677	15.010
Nov-17	90,107	53,004	8,329	4,930	May-19	97.548	62.076	17.736	5.115
Dec-17	65,734	38,846	9,840	10,188	Jun-19	111.119	48.892	17.779	6.610
Jan-18	93,449	37,774	3,926	8,950	Jul-19	57.025	42.769	14.256	-
Feb-18	70,926	43,173	9,251	11,500	Aug-19	103.720	49.752	15.179	3.550

4.2. Normality Data Test

In testing the normality of demand data, Lilliefors method are tested on Microsoft Excel, with an α value of 0,05 dan n value of 36 period. value |F(Zi)-S(Zi)| 0,084012363. and as we can see that Lo < Ltabel, it means the data normally distributed.

4.3. Forecasting Using Artificial Neural Network

here is the step of backpropagation artificial neural network, can be seen in Figure 2.

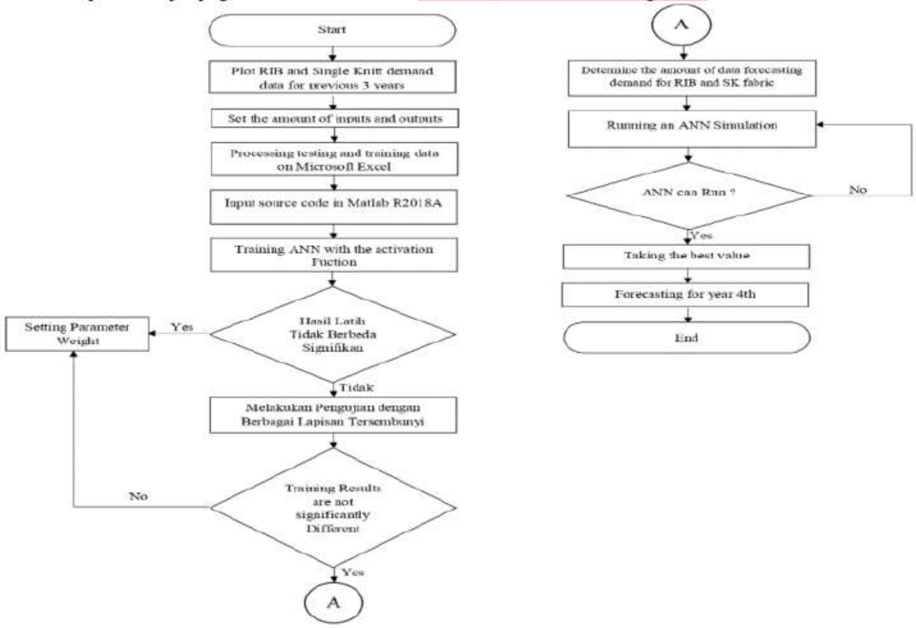

Figure 2. Backpropagation Artificial Neural Network Flowchart.

The steps in forecasting ANN flowchart begin with inputting the results of ANN that have been obtained in the period of the previous year (i.e. the last three year) to predict the coming year (fourth year). After the artificial neural network has been designed the same results as the training target, the next step is forecasting. The following are the results of forecasting Backpropagation Neural Networks which can be seen in Table 2.

Table 2. ANN forecasting for 4th Year

RIB 1X1	RIB 2X1	RIB 5X2	SINGLE KNITT
97803	50736	1666	9684
93694	44092	6908	4991
82358	43810	9958	10578
70353	33637	20376	8582
66463	45024	7976	9162
98576	50671	3187	5680
77077	43123	5318	9870
103238	40043	20491	8057
75119	49348	20609	8871
78095	41337	10823	9317
70598	41352	1254	2024

4.4. Forecasting control by moving range and tracking signal
The following is the result of controlling the moving range and tracking signal which can be seen in Figure 3.

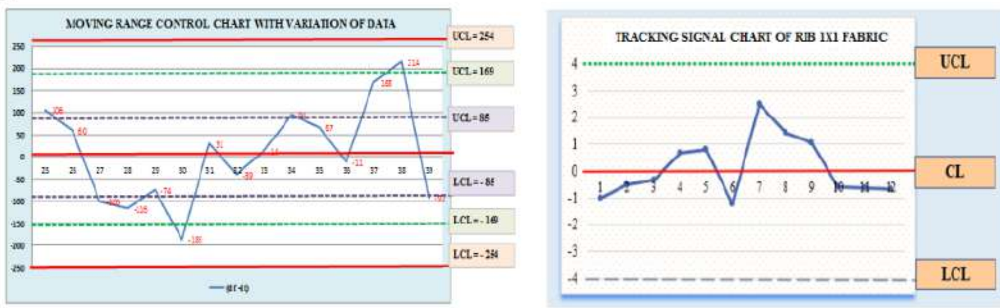

Figure 3. Moving Range and Tracking Signal Chart

Based on the moving range control map and tracking signal, all the demand data spread in the control limits.

4.5. Aggregate Planning
In aggregate planning at PT. ZYX doesn't applied subcontracts method. The Aggregate planning cost shows in Table 3.

Table 3. Aggregate Planning Cost

No.	Cost types	Cost (Rp)
1.	Regular Time Cost	22.780,19075,-/ Hour Product
2.	Over Time Cost	34.170,2861,-/ Hour Product
3.	Inventory Cost	6.750,-/ Hour Product /Period
4.	Hiring Cost	2.500.000,-/person
5.	Firing Cost	3.000.000,-/person

The standard time of the production process of RIB and SK fabrics starts from installing yarn, knitting, weighing, inspection, sewing, dyeing, washing, extortion, drying, cutting fabric. The total standard processing time can be seen in Table 4.

Table 4. Total Standard Time Process

Process	Process time in minute /Kg fabric			
	RIB 1X1	RIB 2X1	RIB 5X2	SINGLE KNIT
Total standard time (minute)	3,5099	3,5093	3,5068	3,3322

The regular production time is obtained from the total working days a week x the number of weeks in a month x the total number of workers x total 1 hours working day x conversion hours to minutes so 5 x 4 x 63 x 7 x 60 so

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that the regular production time of 529,200 minutes is obtained. The calculation results table can be seen in Table 5.

Table 5. Total Production Demand and The Production Regular Time (September 2019- August 2020)

Periode	RIB 1X1	RIB 2X1	RIB 5X2	SK	TOTAL	Prod Reg Time (minutes)
Sep-19	343.278	178.049	5.842	32.269	559.438	529.200
Oct-19	328.855	154.733	24.225	16.631	524.444	529.200
Nov-19	289.067	153.743	34.921	35.248	512.979	529.200
Dec-19	246.931	118.043	71.455	28.597	465.025	529.200
Jan-20	233.278	158.003	27.970	30.529	449.781	529.200
Feb-20	345.991	177.821	11.176	18.927	553.914	529.200
Mar-20	270.532	151.332	18.649	32.889	473.402	529.200
Apr-20	362.354	140.524	71.858	26.847	601.583	529.200
May-20	263.659	173.178	72.272	29.560	538.668	529.200
Jun-20	274.105	145.065	37.954	31.046	488.169	529.200
Jul-20	247.791	145.117	4.398	6.744	404.050	529.200
Aug-20	332.608	169.675	25.014	32.805	560.102	529.200

4.5.1. Aggregate planning with Labour Control Method

Planning with labour control method (chase strategy) can be seen in table 6.

Table 6. Aggregate planning with labour control strategy Method

Periode	Demand	Prod Reg Time	(+)TK	(-)TK	Labour Number	Production Cost (Rp)	Cost(+) TK (Rp)	Cost (-) TK (Rp)
Sep-19	559.438	529.200	1	-	64	212.401.551,76	10.000.000	-
Oct-19	524.444	529.200	-	-	63	199.115.635,03	-	3.000.000
Nov-19	512.979	529.200	-	-	63	194.762.691,83	-	6.000.000
Dec-19	465.025	529.200	-	1	62	176.556.112,40	-	24.000.000
Jan-20	449.781	529.200	-	1	62	170.768.237,33	-	27.000.000
Feb-20	553.914	529.200	1	-	64	210.304.563,26	7.500.000	-
Mar-20	473.402	529.200	-	1	62	179.736.366,45	-	21.000.000
Apr-20	601.583	529.200	1	-	64	228.402.780,93	22.500.000	-
May-20	538.668	529.200	1	-	64	204.516.173,16	2.500.000	-
Jun-20	488.169	529.200	-	1	62	185.343.197,11	-	15.000.000
Jul-20	404.050	529.200	-	1	62	153.405.689,28	-	45.000.000
Aug-20	560.102	529.200	1	-	64	212.653.976,23	10.000.000	-
					Total	2.327.966.975	52.500.000	141.000.000

*cost production value = demand x regular cost in minute
*cost value (+)/(-) TK = demand of hiring or firing x hiring or firing cost

4.5.2. Aggregate with Inventory Control Method

The breakdown of some costs in aggregate production planning can be seen in Table 7.

Table 7. Aggregate Planning Cost

Cost Types	**Cost**
Regular production cost in minute	Rp, 379,67/minute. Product
Inventory cost in minute	Rp 112.500,-/minute product/period.

Aggregate planning with control methods can be seen in Table 8.

Table 8. Aggregate planning with inventory control strategy (Level Strategy) Method

Period	Demand	Demand cum	Prod RT	Prod Cum RT	Inventory	adjustment	Production Cost (Rp)	Inventory Cost (Rp)
Sep-19	559.438	559.438	529.200	529.200	- 30.238	-	200.921.282	**-**
Oct-19	524.444	1.083.882	529.200	1.058.400	- 25.482	4.755,8356	200.921.282	**535.032**
Nov-19	512.979	1.596.861	529.200	1.587.600	- 9.261	20.976,7461	200.921.282	**2.359.884**
Dec-19	465.025	2.061.886	529.200	2.116.800	54.914	85.151,3712	200.921.282	**9.579.529**
Jan-20	449.781	2.511.667	529.200	2.646.000	134.333	164.570,4913	200.921.282	**18.514.180**
Feb-20	553.914	3.065.581	529.200	3.175.200	109.619	139.856,1745	200.921.282	**15.733.820**
Mar-20	473.402	3.538.983	529.200	3.704.400	165.417	195.654,4324	200.921.282	**22.011.124**
Apr-20	601.583	4.140.566	529.200	4.233.600	93.034	123.271,8115	200.921.282	**13.868.079**
May-20	538.668	4.679.234	529.200	4.762.800	83.566	113.803,3462	200.921.282	**12.802.876**
Jun-20	488.169	5.167.404	529.200	5.292.000	124.596	154.833,9561	200.921.282	**17.418.820**
Jul-20	404.050	5.571.454	529.200	5.821.200	249.746	279.983,7241	200.921.282	**31.498.169**
Aug-20	560.102	6.131.556	529.200	6.350.400	218.844	249.081,3653	200.921.282	**28.021.654**
				Total			2.411.055.389	172.343.166

4.5.3. Aggregate planning with transportation method.
Aggregate planning using transportation methods can be seen in Table 9.

Table 9. Aggregate planning with transportation strategy Method

NEEDS CAPACITY PERIODE		PERIODE 25	26	27	28	29	30	31	32	33	34	35	36	UN-USED CAPACITY	CAPACITY AVAILABLE
25	RT	380 529.200	492	605	717	830	942	1.055	1.167	1.280	1.392	1.505	1.617	-	529200
	OT	570 30.238	682	782	882	982	1082	1182	1282	1382	1482	1582	1682	22.682	52920
26	RT		380 524.444	492 4.756	605	717	830	942	1.055	1.167	1.280	1.392	1.505	-	529200
	OT		570	682	782	882	982	1082	1182	1282	1382	1482	1582	52920	52920
27	RT			380 508.223	492 20.977	605	717	830	942	1.055	1.167	1.280	1.392	-	529200
	OT			570	682	782	882	982	1082	1182	1282	1382	1482	52920	52920
28	RT				380 444.049	492 85.151	605	717	830	942	1.055	1.167	1.280	-	529200
	OT				570	682	782	882	982	1082	1182	1282	1382	52920	52920
29	RT					380 364.630	492 164.570	605	717	830	942	1.055	1.167	-	529200
	OT					570	682	782	882	982	1082	1182	1282	52920	52920
30	RT						380 389.344	492 139.856	605	717	830	942	1.055	-	529200
	OT						570	682	782	882	982	1082	1182	52920	52920
31	RT							380 333.546	492 195.654	605	717	830	942	-	529200
	OT							570	682	782	882	982	1082	52920	52920
32	RT								380 405.928	492 123.272	605	717	830	-	529200
	OT								570	682	782	882	982	52920	52920
33	RT									380 415.397	492 113.803	605	717	-	529200
	OT									570	682	782	882	52920	52920
34	RT										380 374.366	492 154.834	605	-	529200
	OT										570	682	782	52920	52920
35	RT											380 249.216	492 279.984	-	529200
	OT											570	682	52920	52920
36	RT												380 280.119	249.081	529200
	OT												570	52920	52920
PERMINTAAN		559.438	524.444	512.979	465.025	449.781	553.914	473.402	601.583	538.668	488.169	404.950	560.102	853.884	6985.440

4.5.4. Aggregate Planning with Mixed Strategy
The following is an aggregate planning table with Mixed Strategy which can be seen in Table 10.

Table 10. Aggregate Planning with Mixed Strategy Method

Period	Demand	Prod Reg Time	Additional needs	Prod OT	RT (+) OT	Inventory	Overtime cost (Rp)	Inventory Cost (Rp)	Production Cost
Sep-19	559.438	529.200	30.238	52.920		-	16.536.998	3.936.750	212.401.552
Oct-19	524.444	529.200	-4.756	52.920		34.993		5.226.571	199.115.635
Nov-19	512.979	529.200	-16.221	52.920		46.458		10.621.364	194.762.692
Dec-19	465.025	529.200	-64.175	52.920		94.412		12.336.370	176.556.112
Jan-20	449.781	529.200	-79.419	52.920		109.657		621.358	170.768.237
Feb-20	553.914	529.200	24.714	52.920		5.523		9.679.023	210.304.563
Mar-20	473.402	529.200	-55.798	52.920		86.036		1.535.978	179.736.366
Apr-20	601.583	529.200	72.383	52.920	19.463	13.653	11.084.055	8.613.821	228.402.781
May-20	538.668	529.200	9.468	52.920		76.567		14.294.967	204.516.173
Jun-20	488.169	529.200	-41.031	52.920		127.066		23.758.372	185.343.197
Jul-20	404.050	529.200	-125.150	52.920		211.186		6.202.508	153.405.689
Aug-20	560.102	529.200	30.902	52.920		55.133			212.653.976
					Total		11.084.055	96.827.087	2.327.966.974

Description:
Additional Needs The results are obtained by comparing regular time production time with existing needs.
Overtime production is obtained from company interviews where total overtime is 10% of regular time
Demand RT (+) OT is obtained from seeing whether additional requirements are still less than overtime production

Comparison of production costs with some aggregate methods can be seen in Table 11.

Table 11. Comparison of some aggregate method cost

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	The method used	Total Production Cost
1.	Labor Control (Chase Strategy)	Rp 2,521.466.975,-
2.	Inventory Control (Level Strategy)	Rp 2.583.398.555,-
3.	**Mixed Strategy**	**Rp 2.435.878.117,-**
4.	Transportation	Rp 2.478.028.621,-

4.6. Analysis of raw material usage (yarn)

The volume of raw material usage from Sep 2016-Aug 2019 can be seen in Table 12.

Table 12. The volume of raw material (yarn) for RIB 1X1

Period 1-36		
1-12	13-24	25-36
202,71	198,84	194,23
82,15	186,10	183,10
150,94	159,08	229,87
90,54	116,05	129,46
109,27	164,98	194,33
119,70	125,22	166,62
131,54	156,77	234,87
183,36	160,23	78,97
242,16	163,55	172,22
130,26	60,24	196,1772

Normality test of raw materials was tested using the Chi Square (x^2) method. Following is an example of calculating thread usage for RIB 1X1 fabric in the past from 36 previous periods. First thing to do is group the data according to class using the rule "Sturges" from the calculation, the total value of the upper limit is 151.16 with 7 classes. Calculation of standard deviation of table is as follows:

$$\bar{x} = \frac{151,16}{7} = 21,6 \text{ so the value of deviation standard is s} = 60,7$$

Next hypothesis testing, namely $X^2_{test} = \frac{\Sigma(F-\theta_i)^2}{\theta_i} = 3,4623$

Based on the X^2 calculation table of 9.49. Then the value of H_0 is accepted and normally distributed. Because the data that is known from the company is a probability distribution that follows the normal distribution pattern so to solve it in inventory control the calculation using a dynamic inventory model under the risk.

4.7. Coefficient autocorrelation analysis

From testing the plot results the coefficient values show that each autocorrelation value is positive and tends to increase. The results of the autocorrelation test can be seen in Table 13.

Table 13. Auto correlation test result

Lag	1	2	3	4	5	6	7	8	9	10
Autocorrelation Value	0,1301	0,1644	0,2423	0,2198	0,2197	0,2157	0,2119	0,2099	0,2199	0,2205

4.8. Inventory Control

Table 14. Demand fabric convert from kg to bal (yarn)

Period	X_t (1)	Y'_t (2)	Y't .(grams/M2) (3)	Bal = (3)x0,35/181,44
Sep-19	37	97.803	89.431	172,67
Oct-19	38	93.694	85.674	165,41
Nov-19	39	82.358	75.308	145,40
Dec-19	40	70.353	64.331	124,21
Jan-20	41	66.463	60.774	117,34
Feb-20	42	98.576	90.138	174,03
Mar-20	43	77.077	70.479	136,08
Apr-20	44	103.238	94.401	182,26
May-20	45	75.119	68.689	132,62
Jun-20	46	78.095	71.410	137,87
Jul-20	47	70.598	64.555	124,64
Aug-20	48	94.763	86.651	167,30
Total			921.840	1.779,84
Average monthly thread usage				148,32
Standard Deviation Value				21,75

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The raw material usage test shows that the X^2 test value explains that the use of threads is normally distributed, so the inventory cost calculation can use the "Dynamic Inventory Model under the Risks". Based on forecasting, there were 921,840 kg of RIB 1x1 fabric which is equivalent to 1780 bales of yarn, so that the average monthly usage of thread in the production of 1X1 RIB fabric was 148.32 bales, RIB 2X1 cloth was 78.20 bales, RIB 5X2 cloth was 17 , 02 bales, and for single knit fabrics of 14.22 bales. The width of the fabric is 36 inches or 91.44 cm. For 30's combed cotton fabric the weight of the cloth / m^2 is equivalent to 0.35 kg / m^2, and 1 ball of fabric weighing 181.44 kg. Examples of conversion tables on 1X1 RIB fabric can be seen in Table 14.

4.8.1. Raw material inventory cost with Dynamic Model under the risk

The following is an inventory cost element for calculation data which can be seen in Table 15.

Table 15. Element of inventory cost and data for calculation.

Element		Product			
		RIB 1X1	RIB 2X1	RIB 5X2	SK
1.	Yarn per bal cost	Rp 9.250.000	Rp 9.150.000	Rp 9.100.000	Rp 8.975.000
2.	Average demand per month	148,32 bal	78,20 bal	17,02 bal	14,22 bal
3.	Deviation Standard Value	21,75 bal	8,46 bal	12,12 bal	4,28 bal
4.	Carring cost per bal	Yarn value per bal x 18.75% (percentage of company carring cost)			
		Rp 1.734.375	Rp 1.715.625	Rp 1..706.250	Rp. 1.682.812
5.	Lead time Cost	1 Bulan	1 Bulan	1 Bulan	1 Bulan
6.	Inventory shortage cost	Average demand per month x 20% x yarn per bal cost (Rp)			
		274.391.858,15	143.104.629,03	30.979.909,89	25.526.520,53
7.	Ordering Cost	Average of requirement per month (bal) x 181,44 kg x Ordering cost (Cr) per kg (Rp)			
		1.321.833	**1.194.711**	**1.820.401,11**	**248.287,86**

Description about optimal order number, safety stock dan re-order point.

Deviation standard when lead time

(Si) = 21,75 bal x $\sqrt{1}$ = 21,75 bal

$$g(w) = \sqrt{\left(21{,}75\sqrt{1}\right)^2 \text{x} \frac{2 \text{ x Rp } 9.250.000 \text{ x } 18{,}75\% \text{ x Rp} 1.321.833{,}11}{148{,}32 \text{ bal x } (274.391.890{,}81)2}} = 0{,}0139$$

$$F(R+w) = \frac{1}{(21{,}75\sqrt{1})} \text{ x } 0{,}0139 = 0{,}0006408$$

The value of w is determined from the ordinate of normal probability distribution table from the value of g (w) obtained. So for RIB 1 fabric the value of w is 2.59. Continue to count the order each time the order (t)

$$t = \frac{12 \text{ x Rp } 274.391.890{,}81 \text{ x } 0{,}0006408}{\text{Rp } 9.250.000 \text{ x } 18{,}75\%}, \text{ so t value} = 1{,}22 \text{ month (37 days)}$$

Optimal number order (Xo)

Xo = 1,22 x 148,32 bal = 180,43 bal

Safety Stock

SS = (21,75 bal) x 2,59 = 56,32 bal

Re-Order Point

ROP (P) = 56,32 + (1 x 148,32 bal) = 204,64 bal

Total Inventory Cost

for $\int_{R+w}^{\infty} f(y)\,dy$ value obtained by looking at the location of the value of w in the area table under the normal curve, for fabric RIB 1X1 w = 2.59 so that a value of 0.0048 is obtained.

$$TC = \left(\frac{12 \text{ x } 1.321.833{,}11}{1{,}22}\right) + \left(\frac{1{,}22 \text{ x } 148{,}32 \text{ x Rp } 1.734.375}{24}\right) + (56{,}32 \text{ bal x Rp } 1.734.375) + \left(\frac{12 \text{ x Rp } 274.391.890{,}81}{24} \text{ x } 0{,}0048 \text{ x Rp } 1.-\right)$$

TC = Rp 280.184.325,04.

Recapitulation of calculations with dynamic models can be seen in Table 17.

Table 16. Recapitulation of total inventory cost dynamic model

Description	RIB 1X1	RIB2X1	RIB 5X2	Single Knitt
Lead time	36 Hari	48 hari	127 hari	51 hari
Optimal order	180,43 bal	125,23 bal	72,32 bal	72,30 bal
Safety Stock	56,32 bal	21,99 bal	14,54 bal	6,64 bal
Re-order Point	204,64 bal	100,19 bal	31,57 bal	20,86 bal
Total Inventory Cost	136.755.224	76.754.118	45.170.798	24.965.858

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4.8.2. Inventory Cost according to company policy

The condition of raw material stock Sep 2018-Aug 2019 can be seen in Table 17.

Table 17. the condition of raw material stock in September 2018-August 2019

Early Stock (bal)	Average usage (Bal)	Final stock when the goods enter (Bal)	Stok Condition	Risk (bal)
149	149,51	-0,37	-	Negative – 0,375
177	176,13	1,01	+	-
144	138,68	5,31	+	-
122	110,23	12,02	+	-
162	154,10	8,13	+	-
146	156,12	-9,99	-	Negative -9,995
157	166,63	-9,39	-	Negative -9,394
156	152,44	3,96	+	-
180	174,24	6,19	+	-
182	182,47	-0,48	-	Negative -0,476
97	90,20	6,35	+	-
159	167,01	-8,24	-	Negative -8,239
Total		14,50	Risk	-28,1

Seen in the table that the company has a risk in procuring raw materials. The risk is calculated with a 95% confidence level = 1,96, $\bar{X}(\mu)$ = 1,208176 bal and $S(\partial)$ = 6,92 bal. The following of cost of raw material procurement by company can be seen in Table 18.

Table 18. Costs of procuring raw materials according to the company

No.	**Cost Types**	**Cost**
1.	Ordering Cost	Rp 15.861.997
2.	Carrying cost	Rp 128.621.199
3.	Safety stock cost	**Rp. 2. 095. 430**
4.	The risk company cost	Rp 22.824.861

The following is a recapitulation of yarn raw material inventory costs from the company PT. ZYX as shown in table 19.

Table 19. Recapitulation inventory cost of yarn in PT. ZYX

Cost	RIB 1X1	RIB2X1	RIB 5X2	Single Knitt
Ordering Cost	Rp 15.861.997	Rp 14.336.515	Rp 21.844.855	Rp 2.979.483
Carring Cost	Rp 128.621.199	Rp 67.080.211	Rp 14.521.861	Rp 11.965.670
Safety Stock Cost	Rp 2.095.430	Rp 1.209.120	Rp 1.424.787	Rp 868.226
Company Risk Cost	Rp 22.824.861	Rp 13.170.562	Rp 8.306.267	Rp 41.012.833
Total Inventory Cost	Rp 169.403.487	Rp 95.796.407	Rp 46.097.771	Rp 55.089.759

From the calculations that have been made, it can be concluded that the company method can still be further improved, this is because the cost with the method used by the writer is smaller than the company. The summary summary can be seen in Table 20.

Table 20. Recapitulation of company TIC comparison and dynamic model

Product Description	Inventory Cost		Savings	Percentage (%)
	Company	Dynamic Method		
RIB 1X1	Rp 169.403.487	Rp 136.755.224	Rp 32.649.230	19,27
RIB 2X1	Rp 95.796.407	Rp 60.671.065	Rp 35.125.342	36,67
RIB 5X2	Rp 46.097.407	Rp 45.170.769	Rp 927.002	2,01
SINGLE KNITT	Rp 55.089.759	Rp 21.748.604	Rp 33.341.154	60,52

4.9. Research Recapitulation

The following is a summary of the overall output of the research conducted can be seen in Figure 4.

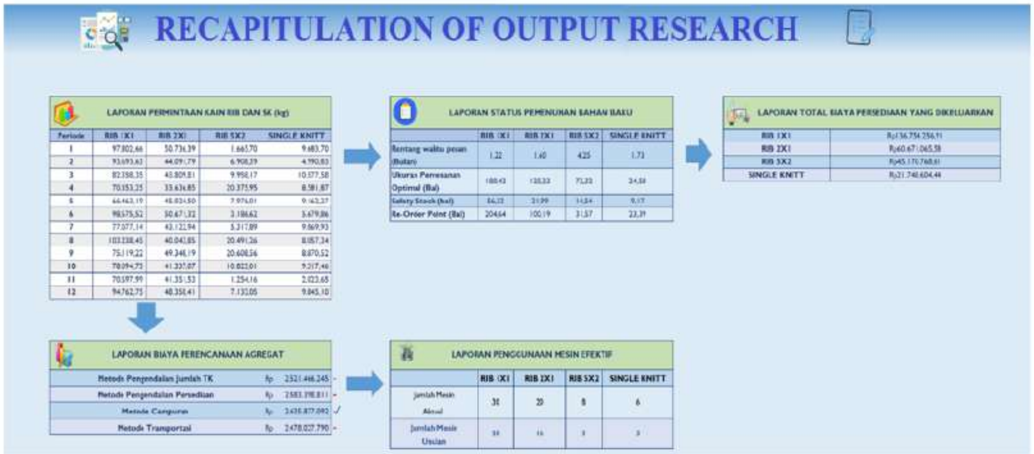

Figure 4. Recapitulation of the research

5. Conclusion

The best aggregate method for PT. ZYX is a mixed strategy method, because it gives the smallest total production cost of Rp 2,355,466,975. The inventory control is classified as dynamic inventory can save cost for 19.27% in RIB 1x1 product; 36.67% in RIB 2X1 product; 2.01% at RIB 5X2 product; 60.52% for single knit product.

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